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Selected US specifications from IPC sub-class H02H

(54) **Surge voltage protection arrangement**

(57) A surge voltage protection arrangement comprises one or more gas discharge tubes such as T1 and includes at least two gaps J and G defined by electrodes of the tubes. Two of the electrodes *a* and *c* which are separated by at least one other electrode *b* are connected between two conductors L1, L2 of a circuit to be protected, and a capacitor C is connected between one of the conductors and the intermediate electrode *b*. The capacitor responds to an impulse overvoltage to cause initial breakdown between the intermediate electrode *b* and the electrode *c* which in turn initiates breakdown between the electrodes *b* and *a*. In this way the impulse sparkover voltage can be made to approximate to the D.C. sparkover voltage. The arrangement may employ triggered gas discharge tubes, or two-electrode gas discharge tubes, or a combination of both types of tube. The tubes may have ignition stripes I and radioactive dopants.

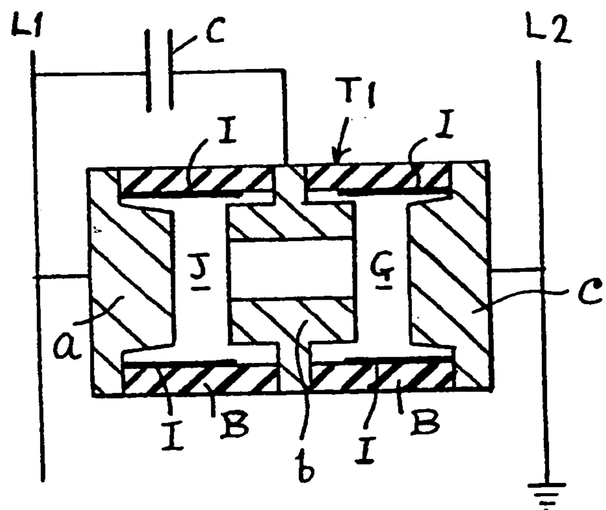

Fig. 6

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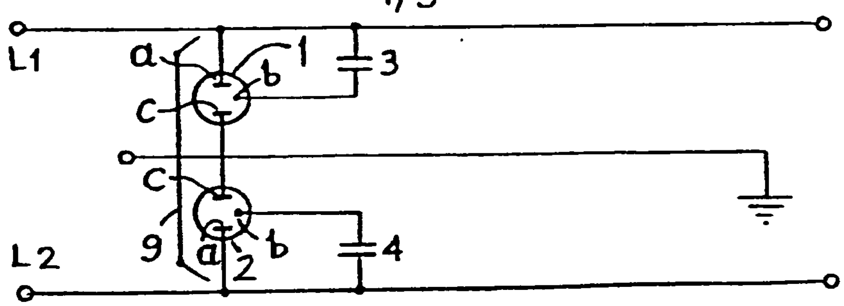

Fig.1

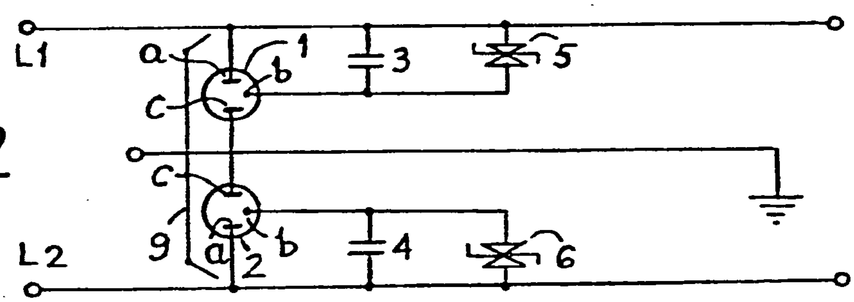

Fig.2

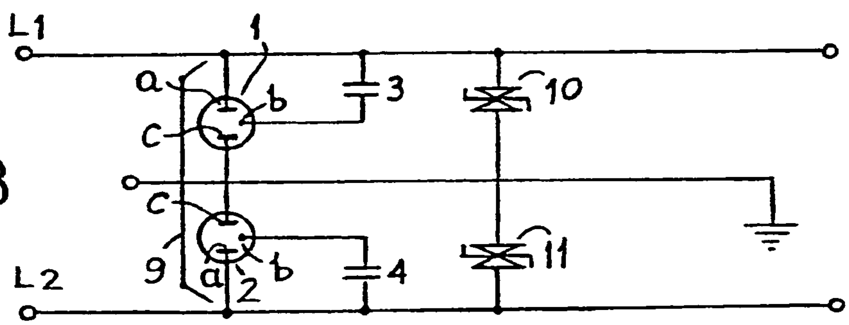

Fig.3

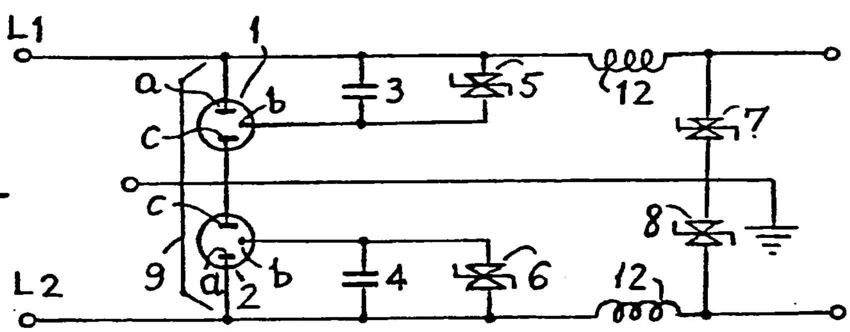

Fig.4

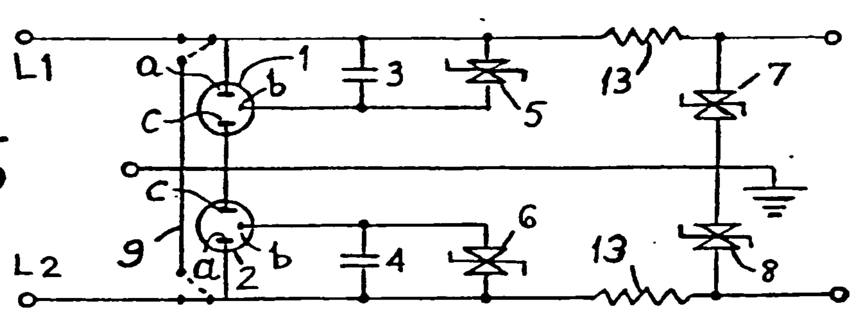

Fig.5

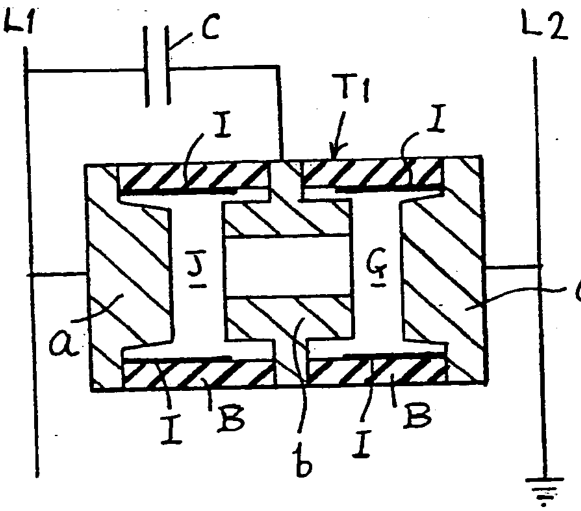

Fig. 6

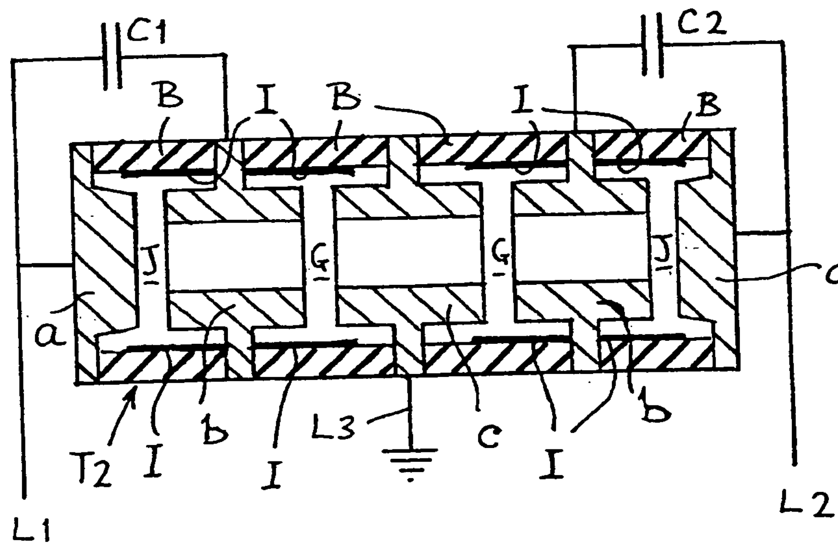

Fig. 7

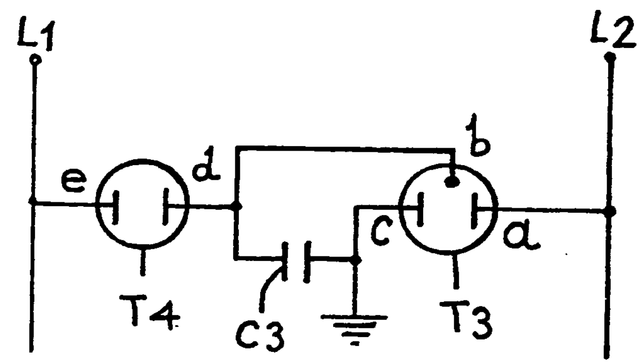

Fig.8

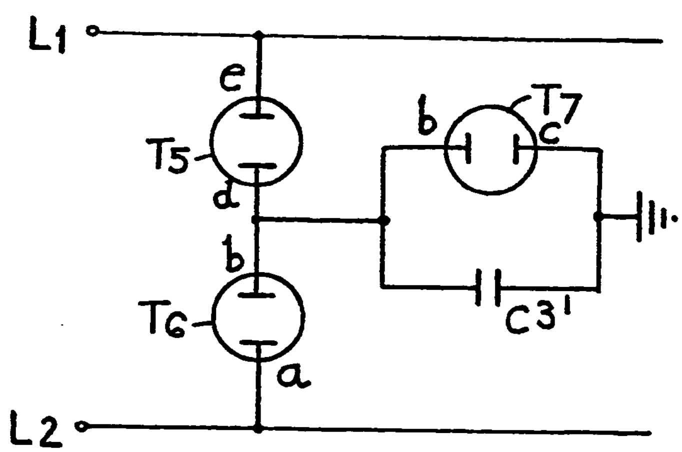

Fig.9

gap J or G. As an example, if the tube T1 is designed to have a static breakdown voltage across each gap of 90 volts, the D.C. sparkover voltage across the tube will be approximately 180 volts.

Dynamic Breakdown Mode of Operation

The tube T1 is designed such that the dynamic to static breakdown of a single gap, either J or G, is in the ratio of approximately 2:1. Thus, in the example given above, the dynamic breakdown voltage across each gap is approximately 180 volts giving a dynamic sparkover voltage across the tube of approximately 360 volts. However, by reason of the capacitor C, a dynamic overvoltage such as is caused by a short duration impulse voltage or transient, will initially cause the tube T1 to break down across gap G via the capacitor C. The gap G thus becomes a near short circuit and a second breakdown immediately occurs across gap J, which also becomes a near short circuit. It can be seen that the two dynamic breakdowns occur one after another but at approximately half the voltage of a dynamic breakdown across both gaps J and G, i.e. at approximately 180 volts instead of approximately 360 volts.

Hence the self-triggered tube T1 can protect against both dynamic and static overvoltages at substantially the same protection level.

From the foregoing it follows that the important parameters in order to have low level protection are:

(a) Low static single gap breakdown voltages which are approximately half that of the protection voltage required.

(b) A dynamic to static breakdown voltage ratio of e.g. 2:1, so that the maximum impulse protection voltage will be substantially the same as that of the static protection overvoltage level.

In the embodiment of Figure 7, a five electrode tube T2 is connected across a pair of lines L1, L2 balanced with respect to a grounded line L3. The tube T2 is constructed in basically similar manner to the tube T1 and corresponding parts bear the same references. As can be seen, the tube has two trigger electrodes *b* which are respectively disposed between an end electrode *a* and a common centre electrode *c* which is connected to the grounded line L3. Capacitors C1 and C2 are respectively connected between the lines L1, L2 and one of the trigger electrodes *b*. Thus, the tube T2 can be considered to be the equivalent of two of the tubes T1 of Figure 1 connected back to back. The manner of operation of Figure 2 is similar to that described for the arrangement of Figure 1, for each half of the balanced line arrangement.

Clearly other gas discharge tube configurations are possible besides those specifically described. For example the trigger electrodes may be other than annular and the ignition electrodes may take various different forms.

Figure 8 shows a further embodiment of circuit arrangement according to the invention comprising both a triggered gas discharge tube T3 and a two electrode gas discharge tube T4 connected across a pair of balanced lines L1, L2. A capacitor C3 is connected between the trigger electrode *b* and that electrode *c* of the tube T3 which is connected to earth. The trigger electrode *b* is also connected to one electrode *d* of the tube T4, whilst the remaining electrodes *a* and *e* of the tubes T3 and T4 are connected respectively to the lines L2 and L1.

As in the previous embodiments, the arrangement in effect provides two parallel paths to earth from each line, one path being through two spark gaps in series and the other path being through a spark gap and the capacitor C3 is series. The two gaps in series are arranged to breakdown at approximately twice the voltage of one gap alone, whilst the one gap and capacitor in series breakdown in the case of an overvoltage transient at the sparkover voltage of that gap. This is comparable to twice the D.C. sparkover voltage of that gap and therefore the impulse sparkover voltage approximates to the D.C. sparkover voltage.

Figure 9 shows a circuit arrangement according to the invention employing three two electrode gas discharge tubes T5, T6, T7 and a capacitor C3′ connected as shown between two balanced lines L1, L2 and earth. This circuit is in fact the electrical equivalent of that of Figure 8 and similar reference letters *a* to *e* have been used for the corresponding electrodes.

The capacitors employed in the arrangements according to the invention may typically have values between 1 and 5 nF and form energy storage capacitors so far as transient overvoltage impulses are concerned. The self-capacitance of the gas discharge tubes may typically be 2 or 3 pF so the capacitors employed are relatively large with respect to the self-capacity of the circuit.

Using a 10/700 μS 5Kv peak test pulse the circuit arrangements according to the invention have been shown to give a dynamic overvoltage protection at a voltage level substantially equal to the static D.C. protection.

In this specification the references to the D.C. sparkover voltage or static breakdown voltage are references to the voltage at which the gas discharge tube sparks over with an applied D.C. voltage which increases so slowly as to make the D.C. sparkover voltage virtually independent of the rate of rise of the applied voltage, e.g. a voltage rise of up to 10^2 V/Sec. Furthermore, the references to the impulse sparkover voltage or dynamic breakdown voltage are references to the highest voltage which appears across either line and the earth terminal in the period between the application of an impulse voltage of defined wave shape and the time when current begins to flow between these terminals, e.g. a voltage rise in the region of 10^9 V/Sec.

CLAIMS

1. A surge voltage protection arrangement comprising one or more gas discharge tubes, and including at least two spark gaps defined by electrodes of said one or more gas discharge tubes wherein two first electrodes, which are separated by at least one other electrode, are connected between two conductors of a circuit to be protected and wherein a capacitor is connected between said at

least one other electrode and one of said conductors, said capacitor responding to an impulse overvoltage to cause initial breakdown between said at least one other electrode and one of said first electrodes which in turn initiates breakdown between said at least one other electrode and the second of said first electrodes.

2. An arrangement as claimed in claim 1, in which the arrangement provides two parallel paths to earth or other reference potential, one of said paths being through two spark gaps effectively in series and the other path being through one of said spark gaps and the capacitor in series.

3. An arrangement as claimed in claim 1 or 2, in which the capacitor is a discrete component.

4. An arrangementas claimed in claim 1 or 2, in which the capacitor is formed as an integral part of a gas discharge tube.

5. An arrangement as claimed in any preceding claim, in which there is used one or more gas discharge tubes having two main electrodes and an intermediate so-called trigger electrode which forms the at least one other electrode, whereby two spark gaps are defined within a single tube.

6. An arrangement as claimed in any of claims 1 to 4, in which the two spark gaps are formed by providing plural two electrode gas discharge tubes connected together and said at least one other electrode is formed by the interconnected electrodes of two tubes.

7. An arrangement as claimed in any of claims 1 to 4, including both one or more two electrode gas discharge tubes and one or more gas discharge tubes incorporating a trigger electrode.

8. An arrangement as claimed in any preceding claim, in which the dynamic to static breakdown of a single gap is in the ratio of approximately 2:1 and two gaps in series are arranged to breakdown at approximately twice the voltage of one gap alone.

9. An arrangement as claimed in any preceding claim, in which a clamping device, such as a diode, is connected between the at least one other electrode and one of said conductors to be protected.

10. An arrangement as claimed in any preceding claim, in which a clamping device, such as a diode, is connected across the two conductors to be protected.

11. An arrangement as claimed in any preceding claim in which a thermally responsive overload protection device is associated with the gas discharge tube or tubes.

12. A triggered gas discharge tube having two axially spaced electrodes and an intermediate trigger electrode between said electrode thereby defining two spark gaps in said tube, at least one ignition means and the geometry of said ignition means in conjunction with the emissive, as well as the gas type and pressure within the tube being such that the dynamic breakdown voltage of each gap of the tube is approximately twice the static breakdown voltage of the gap.

13. A tube as claimed in claim 12, comprising a multi-electrode triggered gas discharge tube having two axially spaced end electrodes an intermediate annular electrode equispaced between and co-axial with said end electrodes, a trigger electrode disposed between each end electrode and said intermediate electrode and ignition means associated with at least some of the electrodes.

14. A tube as claimed in claim 12 or 13, in which the trigger electrode or electrodes are annular electrodes co-axial with the end electrodes and intermediate electrode and equispaced therebetween.

15. A tube as claimed in claim 12, 13 or 14, in which the ignition means comprise strip-like electrodes.

16. Surge voltage protection arrangements substantially as hereinbefore described with reference to the accompanying drawings.

17. Triggered gas discharge tube substantially as hereinbefore described with reference to the accompanying drawings.

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SPECIFICATION

Surge voltage protection arrangements

The present invention relates to surge voltage protection arrangements employing one or more gas discharge tubes in order to provide protection for electrical or electronic equipment against undesirable high voltage surges or overvoltages, particularly those of very high level and very short duration.

Such surge protection arrangements employing gas discharge tubes have become increasingly necessary in connection with equipment employing semiconductor chips or integrated circuits which are particularly sensitive to and liable to damage by very short duration spikes or transients of very high voltage levels.

One of the problems encountered in achieving effective surge voltage protection is the response of the gas discharge tubes employed to an applied voltage which is high enough to strike the tube. In practice there is a considerable difference between the performance of a gas discharge tube in response to an applied D.C. voltage and the performance in response to an applied impulse voltage. Thus the D.C. sparkover voltage of a gas discharge tube tends to be much lower than the impulse sparkover voltage. The ratio may be of the order of 1:2.

It would clearly be desirable if the impulse voltage breakdown level of a gas discharge tube could be made to be substantially the same as the D.C. voltage breakdown level and the present invention provides means whereby this may be achieved.

From one aspect the invention provides a surge voltage protection arrangement comprising one or more gas discharge tubes and including at least two spark gaps defined by electrodes of said one or more gas discharge tubes, wherein two first electrodes which are separated by at least one other electrode are connected between two conductors of a circuit to be protected and wherein a capacitor is connected between said at least one other electrode and one of said conductors, said capacitor responding to an impulse overvoltage to cause initial breakdown between said at least one other electrode and one of said first electrodes which in turn initiates breakdown between said at least one other electrode and the second of said first electrodes. By means of such an arrangement the gas discharge tube effectively breaks down at a lower value of applied impulse voltage and hence provides improved protection to the circuit.

The arrangement according to the invention may be regarded as providing two parallel paths to earth or other reference potential, one of which is through two spark gaps effectively in series and the other of which is through a spark gap and the capacitor in series.

The capacitor may either be a discrete component or may be formed as an integral part of a gas discharge tube.

In some preferred forms of the circuit arrangement according to the invention, there is used one or more gas discharge tubes having two main electrodes and an intermediate or so-called trigger electrode forming the at least one other electrode, whereby two gaps are defined within a single tube. However, in other preferred forms of the invention the two gaps may be provided by using plural two electrode gas discharge tubes connected together. In this case the at least one other electrode is formed by the interconnected electrodes of two tubes.

The invention also contemplates arrangements including both one or more two electrode gas discharge tubes and one or more gas discharge tubes incorporating a trigger electrode.

As will be understood in the art, the gas discharge tubes employed in the circuit protection arrangements according to the invention are preferably so designed by the judicious use of low work function emissives, (e.g. the oxides of Group 1a metals), gas mix (e.g. noble gas), geometry, ignition system and possibly radio-active dopants (e.g. tritium) that these tubes provide a wide range of low voltage surge clamping and overvoltage protection.

In some embodiments of the invention a clamping device, such as a diode, may be connected between the at least one other electrode and said one of said conductors in order to clamp the second breakdown between the at least one other electrode and the second of said first electrodes at a lower voltage level than between said at least one other electrode and the one of said first electrodes.

Moreover, a further clamping device, such as a diode, may be connected across the two conductors to be protected so as precisely to clamp the surge voltage prior to the first discharge from the at least one other electrode to one of the first electrodes, thereby further limiting the surge clamp voltage.

If desired, series coordinating elements, such as inductors and/or resistors can be included in the arrangement so as to provide overvoltage protection below that of the static voltage rating of the gas discharge tube or tubes.

If desired, a thermally responsive device may be associated with the gas discharge tube or tubes such that a continuous overvoltage resulting in thermal heating of the tube or tubes initiates operation of the thermally responsive device so as to cause a short circuit across the tube or tubes, or to isolate the circuit to be protected, whereby the protection arrangement will fail safe.

The circuit protection arrangements according to the invention may be employed for protecting either balanced or unbalanced circuits or lines against undesirable voltage surges and overvoltages.

The invention further provides a triggered gas discharge tube having two axially spaced electrodes and an intermediate trigger electrode between said electrodes thereby defining two spark gaps in said tube, at least one ignition means and the geometry of said ignition means in conjunction with the emissive, as well as the gas type and pressure within the tube being such that the dynamic breakdown voltage of each gap of the tube is approximately twice the static breakdown voltage of the gap. In other words, for each gap, the D.C. sparkover voltage is approximately one half the

impulse sparkover voltage.

The emissives employed are preferably one or more oxides of Group 1a metals having a low work function and the gas within the tube may be a noble gas or a mixture of noble gases, whilst the ignition means is preferably of strip-like form. The tube may also include one or more radioactive dopants.

The triggered gas discharge tube may be formed as a multi-electrode triggered gas discharge tube having two axially spaced end electrodes, an intermediate annular electrode equispaced between and co-axial with said end electrodes, a trigger electrode disposed between each end electrode and said intermediate electrode and ignition means associated with at least some of the electrodes.

The trigger electrodes are also preferably annular electrodes co-axial with the end electrodes and intermediate electrode and equispaced therebetween. The ignition means may comprise strip-like electrodes.

The invention will now be further described by way of example with reference to the accompanying drawings, in which:—

Figures 1 to 5 each show a different embodiment of a circuit protection arrangement according to the invention employing gas discharge tubes having a trigger electrode;

Figure 6 is a circuit arrangement for protecting an unbalanced line employing one embodiment of gas discharge tube according to the invention;

Figure 7 is a circuit arrangement for protecting a balanced line employing a further embodiment of gas discharge tube according to the invention;

Figure 8 shows a further circuit arrangement employing both a two electrode gas discharge tube and a triggered gas discharge tube; and

Figure 9 shows a circuit arrangement employing a plurality of two electrode gas discharge tubes.

In each of the embodiments shown in Figures 1 to 5, the circuit to be protected comprises a pair of balanced lines L1, L2 and a ground connection; and the arrangement comprises two triggered gas discharge tubes 1 and 2, each of which has a first main electrode *a* connected to one of the lines, a second main electrode *c* connected to ground and an intermediate or trigger electrode *b*.

In the arrangement of Figure 1, capacitors 3 and 4, which may be considered as high pass filters or energy storage devices for transient overvoltages, are respectively connected between the trigger electrodes *b* of tubes 1 and 2 and the lines L1 and L2. By providing the capacitors 3 and 4, a transient overvoltage applied to either of lines L1 or L2 causes initial breakdown of the associated triggered gas discharge tube between electrodes *b* and *c*. This then triggers breakdown across electrodes *a* and *b* and hence breakdown between the line and ground, thereby providing a lower breakdown voltage and increased overvoltage protection, when a transient surge voltage is applied at either line L1 or L2. The application of an overvoltage above that of the static voltage rating of the protection circuit as shown in Figure 1, causes breakdown across electrodes *a* and *c* of the triggered gas discharge tubes; hence breakdown occurs between lines L1 and L2 and ground.

Figure 2 shows a similar arrangement including semiconductor diodes 5 and 6 which are used to clamp the second breakdown between the electrodes *a* and *b* of the triggered gas discharge tube at a lower voltage than the first breakdown between electrodes *b* and *c* of the triggered gas discharge tube.

The protection circuit as shown in Figure 3 includes diodes 10 and 11 connected between the lines L1, L2 and ground. These diodes are selected to precisely clamp the surge voltage prior to the first discharge between electrodes *b* and *c* of the triggered gas discharge tubes 1 and 2 thereby further limiting the surge clamp voltage.

Figures 4 and 5 show embodiments of the circuit including series coordinating elements such as inductors 12 and resistors 13, which are employed to provide overvoltage protection below that of the static voltage rating of the triggered gas discharge tube in conjunction with diodes 7 and 8.

Each of the circuit arrangements is illustrated as including a thermal switch 9 designed to operate such that a continuous overvoltage which causes thermal heating of the triggered gas discharge tube will operate the thermal switch to provide a short circuit between lines L1, L2 and ground, thereby causing the protection circuit to fail safe.

Another embodiment of the thermal switch can be seen in Figure 5, where the thermal switch is designed, such that a continuous overvoltage will cause the thermal heating of the gas discharge tube to operate the thermal switch so as to isolate the input and ground the output. Alternatively the thermal switch can be designed to ground the input and isolate the output when operated by the thermal heating of the gas discharge tube.

Referring now to Figure 6, the circuit arrangement comprises a three-electrode gas discharge tube T1 connected between a pair of lines L1, L2 to be protected. The line L2 is earthed thereby forming an unbalanced arrangement. The tube T1 comprises two spaced end electrodes *a* and *c* and an intermediate annular trigger electrode *b* co-axial with and equispaced from the end electrodes. The tube body comprises two cylindrical ceramic members B, which serve to space and locate the electrodes and which carry ignition stripes I connected to the end electrodes *a* and *c*. A capacitor C is connected between the non-earthed line L1 and the trigger electrode *b*, and acts as a high pass filter or energy storage device for overvoltage impulses, but not of course for D.C. overvoltages.

By appropriate choice of the ignition stripe geometry, emissive, gas mix and pressure, the gas discharge tube can be made to operate as follows:

Static Breakdown Mode of Operation

A D.C. or slowly increasing overvoltage applied to the conducting line L1 will cause the tube T1 to break down between gaps J and G to the second earthed conducting line L2.

Since the gaps J and G are in series, the breakdown voltage across the end electrodes *a* and *c* will be approximately twice that across a single

SURGE VOLTAGE PROTECTION ARRANGEMENT

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Abstract of **GB2179214**

A surge voltage protection arrangement comprises one or more gas discharge tubes such as T1 and includes at least two gaps J and G defined by electrodes of the one or more gas discharge tubes. Two of the electrodes a and c which are separated by at least one other electrode b are connected between two conductors L1, L2 of a circuit to be protected and a capacitor C is connected between one of the conductors and the intermediate electrode b. The capacitor responds to an impulse overvoltage to cause initial breakdown between the intermediate electrode b and the electrode c which in turn initiates breakdown between the electrodes b and a. In this way the impulse sparkover voltage can be made to approximate to the D.C. sparkover voltage. The arrangement may employ triggered gas discharge tubes, or two electrode gas discharge tubes or a combination of both types of tube.